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SPACECRAFT FIND

LIMITS OF SHELL

PROTECTING EARTH

Some of the more important preliminary results from the National Aeronautics and Space Administration's Pioneer VI and VII interplanetary spacecraft are being presented to the American Geophysical Union at its 48th annual meeting being held in Washington, D. C. April 17 to 20.

The two spacecraft have flown almost 200 million miles in their orbits around the Sun and the scientific information returned to Earth includes:

Limits of the Earth's protective magnetic envelope,
the magnetosphere...

A better definition of the solar atmosphere...

Better data for solar weather forecasts...

Additional information on the solar wind.

A report on the magnetosphere and interplanetary magnetic fields indicates the magnetosphere ends at about 3.5 million miles from Earth going away from the Sun.

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Previous estimates put the limit of the magnetosphere as close as the orbit of the Moon, about 240,000 miles or as far out as 100 million miles.

The papers and those making this report are:

Magnetosphere and Interplanetary Magnetic Field

Papers: Preliminary Pioneer VII Observations of the Effect of the Magnetospheric Tail at 1,000 Earth Radii -- Dr. John H. Wolfe, R. W. Silva, and D. D. McKibbin, Ames Research Center, Mountain View, Calif.

Macrostructure of the Interplanetary Magnetic Field-- Dr. Norman F. Ness and Dr. Leonard F. Burlaga, Goddard Space Flight Center, Greenbelt, Md.

Microstructure of the Interplanetary Magnetic Field -- Drs. Burlaga and Ness.

A summary of the papers follows:

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The magnetosphere protects man from high energy solar particles, and is believed to have allowed evolution of higher forms of life on Earth. It is not a sphere, but probably looks like a very long, stretched-out teardrop or a thick, tapered knitting needle.

The continuous stream of charged particles flowing out from the Sun at around a million miles per hour is known as the solar wind. On the Sun side of the Earth, these particles strike the Earth's magnetic field, creating a shock wave. At this shock front, the solar wind divides and flows around the magnetically protected cavity containing the Earth.

Satellites have measured the distance on the Sun-side from the Earth's surface to this magnetic boundary at about 40,000 miles.

Along the line of the Earth's orbit, spacecraft have found the stretched-out teardrop of the magnetosphere to have a diameter of around 160,000 miles, and the same diameter has been measured 280,000 miles "downwind" from the Earth, 40,000 miles beyond the orbit of the Moon.

The course of the Pioneer VII spacecraft, launched last August, was tailored to try to locate the magnetosphere at 3.5 million miles behind or "downwind" from the Earth.

Besides defining a basic part of the Earth, this knowledge is important to understanding basic particle physics and planetary science.

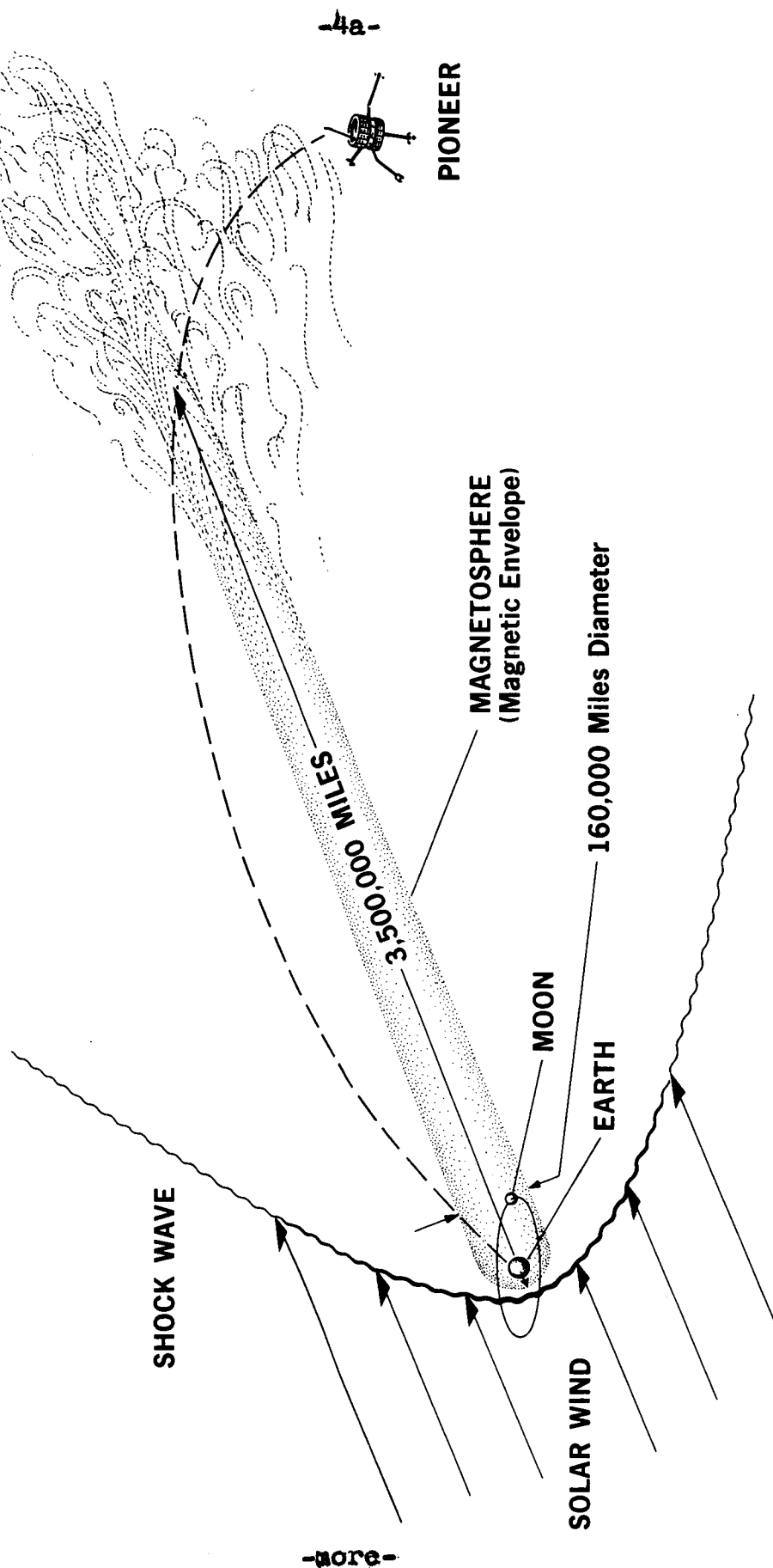
These Pioneer VII results were given by Dr. John Wolfe, of NASA's Ames Research Center, Pioneer project scientist; and Dr. Norman Ness, NASA's Goddard Space Flight Center.

The Ames Research Center has project management for the Pioneer series of spacecraft.

Based on measurements of the Ames solar wind experiment, Dr. Wolfe says Pioneer VII appears to have found not the true magnetosphere, but the tip of the tail of the magnetosphere and its turbulent wake.

Pioneer VII flew through portions of what appeared to be the tail or wake of the Earth's magnetosphere from Sept. 25 to Oct. 1, 1966, at distances ranging from 3,515,181 miles from the Earth to 4,196,817 miles. At first encounter with wake phenomena, the solar wind declined to less than 1/100th of its normal strength for several minutes, and afterwards numbers of solar particles fluctuated violently for various periods of time over the next six days.

EARTH'S PROTECTIVE SHEATH, THE MAGNETOSPHERE, ENDS AT APPROXIMATELY 3.5 MILLION MILES



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A preliminary analysis of magnetic field measurements, reported Dr. Ness, indicates that while phenomena at 3.5 million miles are very complex, the magnetic field appears at times to be connected to the Earth. They have the proper strength and are aligned with the Earth-Sun line.

Summarizing all data so far available from Pioneer VII and other spacecraft, Dr. Wolfe says the evidence suggests that the Earth's true magnetosphere extends a long distance beyond the Moon, ending at around the 3.5-million-mile mark. It probably varies substantially in length with solar activity. It appears to have a turbulent wake extending an unknown distance beyond.

Two other explanations of the Pioneer VII data are that the Earth's field is so weak at 3.5 million miles that solar particles have penetrated the magnetosphere--or "pieces" of the magnetosphere may be breaking off and blowing "downwind".

However, each explanation is consistent with the suggestion that the magnetosphere ends somewhere short of 3.5 million miles.

At first encounter with the wake, Pioneer VII was 99,075 miles above the Earth-Sun line, and at last encounter was 114,927 miles above this line. Since the solar wind blows out from the Sun roughly in straight lines, the wake should be on this line.

However, each time the wake was detected, the solar wind was blowing somewhat upward. This fits the Pioneer VI finding that the solar wind does not blow in exactly straight lines.

Apparently, the spacecraft detected the wake when it was blown upward to the spacecraft. The fact that the wake is blown around in space would also account for intermittent sightings over six days, says Dr. Wolfe.

Detailed reduction of data from the Pioneer VII plasma probe experiment by Dr. Herbert S. Bridge of the Massachusetts Institute of Technology, may add to information on the Magnetosphere.

The trajectory of Pioneer C (Pioneer VIII with successful launch late this year), now being charted, may be planned to come somewhere inside 3.5 million miles, according to Charles F. Hall, Pioneer Project Manager. This would further pin down the end of the Earth's magnetosphere. (Summaries of several more papers on Pioneers VI and VII are attached.)

Cosmic Ray Observations

Paper: "Pioneer VI and VII Observations of Solar Induced Cosmic Radiation"-- Dr. R. P. Bukata, Dr. K. P. McCracken, and Dr. U. R. Rao, Southwest Center for Advanced Studies, Dallas, Tex.

The Southwest Center for Advanced Studies detectors on Pioneer VI and VII measure differences in quantities of low energy (less than 100 million electron volts) cosmic ray particles coming from one direction than from another.

The SCAS experimenters then seek to determine how these differences in direction depend on the three-dimensional configuration of the interplanetary medium, and whether they change with time.

Summaries are as follows:

1. During 1966, a quiet year for solar activity, more than 30 cases of cosmic ray particles generated by solar flares were observed. In each case, there was strong trapping of these solar cosmic rays within the inner solar system (inside the orbit of Mars). That is, once thrown off by the Sun, these cosmic rays tended to stay in the inner solar system for periods of up to several days. In some cases, time and intensity variations of these cosmic ray particle arrivals at the spacecraft were extremely complicated.

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2. As reported previously by SCAS, the solar cosmic ray particles seemed to travel in well-defined streams following the filament structure of the interplanetary magnetic field.

3. Galactic cosmic rays (higher energy particles from outside the solar system) often were reduced in number for varying times. These reductions frequently occurred in 27 day cycles (the time of one solar rotation), and resulted from deflections of these galactic particles away from the inner solar system by strong but temporary interplanetary magnetic fields.

These strong fields result from a magnetic compression at the boundary where a fast moving mass of the solar wind overtakes a slower mass. Such fast moving masses appear to be generated by hot spots of the solar disc and these magnetic compression regions appear to co-rotate with the Sun.

4. Energetic storm particle events also have been observed. These seem to be solar cosmic ray particles originally generated by a solar flare and shunted around the inner solar system for varying periods of time.

These solar storm particles were detected when turbulent solar wind masses passed the spacecraft. These particles come primarily from one direction. They seem to be accelerated to higher energies within the shock fronts caused by collision with wind masses.

Earth's Bow Shock Wave and Interplanetary Electron Temperatures

- Papers: 1. Pioneer VI Observations of Plasma Ion and Electron Eating at the Earth's Bow Shock-- Dr. J. H. Wolfe, R. W. Silva, D. D. McKibbin, Ames Research Center
2. The Interplanetary Solar Wind Electron Characteristics--Dr. J. H. Wolfe, R. W. Silva, D. D. McKibbin, Ames Research Center.

As it left the Earth on Dec. 16, 1965, Pioneer VI passed through the Earth's bow shock wave, which is gas in an extremely steady state condition.

The spacecraft made a large number of measurements of ionized particles, electrons, and magnetic fields. These included the first measurements of flow direction in the bow shock, and the first measurements of electron temperatures.

Significant instantaneous changes in flow directions were seen as the spacecraft passed through the shock wave.

Solar wind electrons arriving at the shock wave created by the Earth's magnetic field had temperatures of around 100,000 degrees Centigrade and heated to 750,000 degrees C. at the shock wave itself. They then cooled immediately after passing the shock front to about 300,000 degrees C.

On each side of the boundary of the Earth's magnetosphere characteristics of electrons were found to be almost identical. This is consistent with the idea that solar wind electrons are injected directly into the Earth's magnetosphere and then accelerated to high energies by the Earth's magnetic field to form the outer Van Allen belt.

Temperatures of electrons in interplanetary space have been measured for the first time by both Pioneers VI and VII along their entire trajectories. These temperatures have proved to be about twice as high as the temperature of the positive particles in the solar wind.

Some theoretical calculations had put the temperature differences between the interplanetary electrons and the ionized particles at far higher values.

Solar Wind Temperature

Paper: The Magnetic-Field-Aligned Thermal Anisotropy-- R. W. Silva, Dr. J. H. Wolfe, D. D. McKibbin, Ames Research Center

Temperature is generally defined as the amount of random motion of molecules in a solid or gas. The random motion increases as energy is applied in the form of heat.

In the solar wind, the motions of particles, which correspond to temperature on the Earth, are less random. These motions continue random in one direction. However, in a perpendicular direction they are controlled by the shape of the interplanetary magnetic field, which extends out from the Sun in a long spiral.

The reason for this is that particles moving in the direction of the magnetic field are not affected by the field, but all others are.

One result of this is that particle temperature measured in one direction is different than it is when measured at right angles to this direction.

Rapid changes in the interplanetary field are accompanied by immediate changes in the temperature orientation. Spacecraft data based on long term averages have indicated dependence of temperature on direction. However, the measurements by the Pioneer VI and VII solar winds experiments have provided the first direct measurements of this relationship between the thermal properties of the solar wind and the interplanetary field.

This data is important to the basic physics of particles and fields.

Bow Shock Measurements

Paper: Analysis of the Earth's Bow Shock Under Steady State Conditions--Dr. C. P. Sonett, Dr. J. H. Wolfe, R. W. Silva and D. S. Colburn - Ames Research Center.

As it left the Earth on Dec. 16, 1965, Pioneer VI passed the Earth's bow shock wave and made the most accurate measurements yet taken. The bow shock happened to be in an extremely steady state condition.

The Earth's bow shock is the shock wave created in the solar wind when it strikes the Earth's magnetic field. This shock wave is believed to form a shallow cone much like a shock wave in front of a supersonic aircraft. The Earth's field behaves like an aircraft in a wind tunnel deflecting the solar wind beside and around it.

However, the shock wave in the solar wind is collisionless. The particles in the solar wind do not strike other particles nor a solid surface and get deflected. Instead, the magnetic field carried by the solar wind particles strikes the magnetic field of the Earth. The solar wind field itself is deflected and it in turn deflects the solar wind particles.

Understanding this mechanism is significant in the important new field of magnetohydrodynamics, which is the study of charged electrically conducting fluids in magnetic fields.

Both the magnetic field and solar wind instruments on Pioneer VI measured the bow shock.

These precise measurements of an extremely large scale magnetohydrodynamic shock wave under steady conditions confirmed theoretical calculations of shape and behavior of such shock waves.

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